TSC
Digital
Solutions for
Spectral
Requirements

So, What's the Problem?

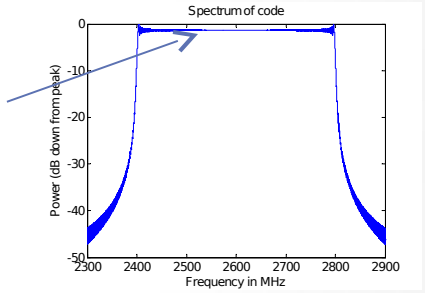
- The Radio Frequency (RF) Spectrum is becoming an increasingly scarce resource
- The result is a reduction in RF Spectrum availability for military systems, and it gets worse every year.
- However, military radar requirements for higher range resolution require the coherent use of broader portions of the RF spectral bands.
- In spectrally crowded environments this results in multiple overlaps with narrower sub-bands occupied by other RF systems.

Evolving RF systems (RADAR, Communications, etc.) must find ways to work in an increasingly crowded spectral domain.

Hypothetical Radar Example

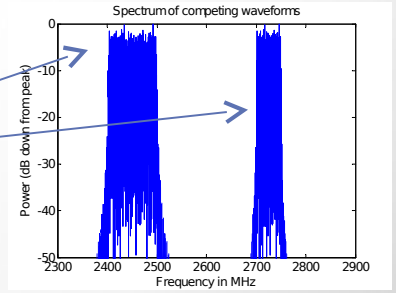
- Mission goals require a high resolution SAR (Synthetic Aperture Radar) image
  - Such a high resolution image requires broadband waveform transmission
  - Available radar can operate in frequency range from 2.4 GHz to 2.8 GHz

Desired spectrum



- Confounding Issue: Part of spectrum is already occupied
  - Portion between 2.5 and 2.6 GHz being used or reserved
  - Another portion between 2.70 and 2.75 Ghz is also in use

Spectral conflicts exist within the needed band



The Challenge

- In order to use as much of the band as possible, it is necessary to “Notch” out the interfering bands while maintaining the needed resolution

- This is hard to accomplish as many notching options result in highly undesirable consequences

Examples of Possible Techniques With Undesirable Consequences

- Use of a waveform which sweeps continuously through available frequencies and skips the unwanted frequency segments
  - This option requires that either the transmitter be turned off during the skipped segments, creating a discontinuous waveform, resulting in:
    - Inefficient transmitter use, RF reflection in the system with possible damage to electronic components, and possible spectral splatter outside of the band
    - Notch boundaries of far than vertical slopes – which require much increased transmitter off time
    - Significant loss of power and effective bandwidth

Examples of Possible Techniques With Undesirable Consequences

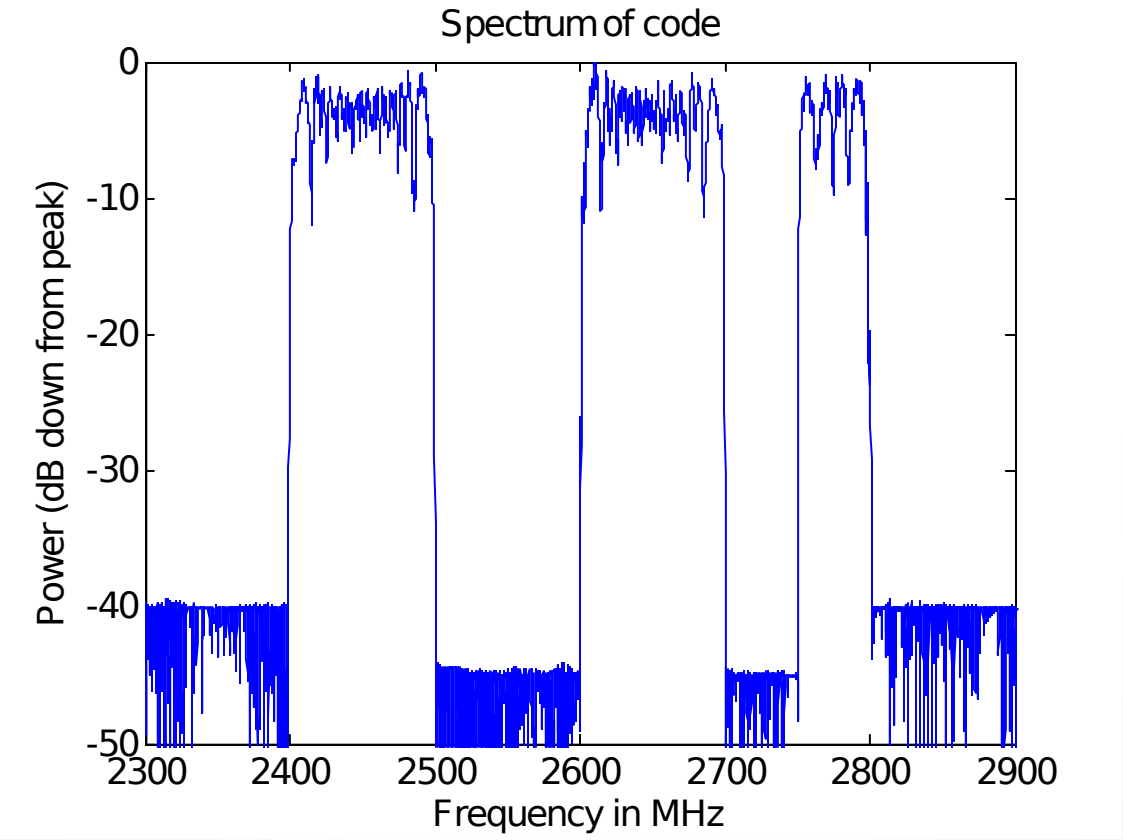
- Use of band-pass filter to filter out unwanted frequency segments
  - Causes amplitude variations in the transmit signal which result in inefficiencies

TSC's Approach

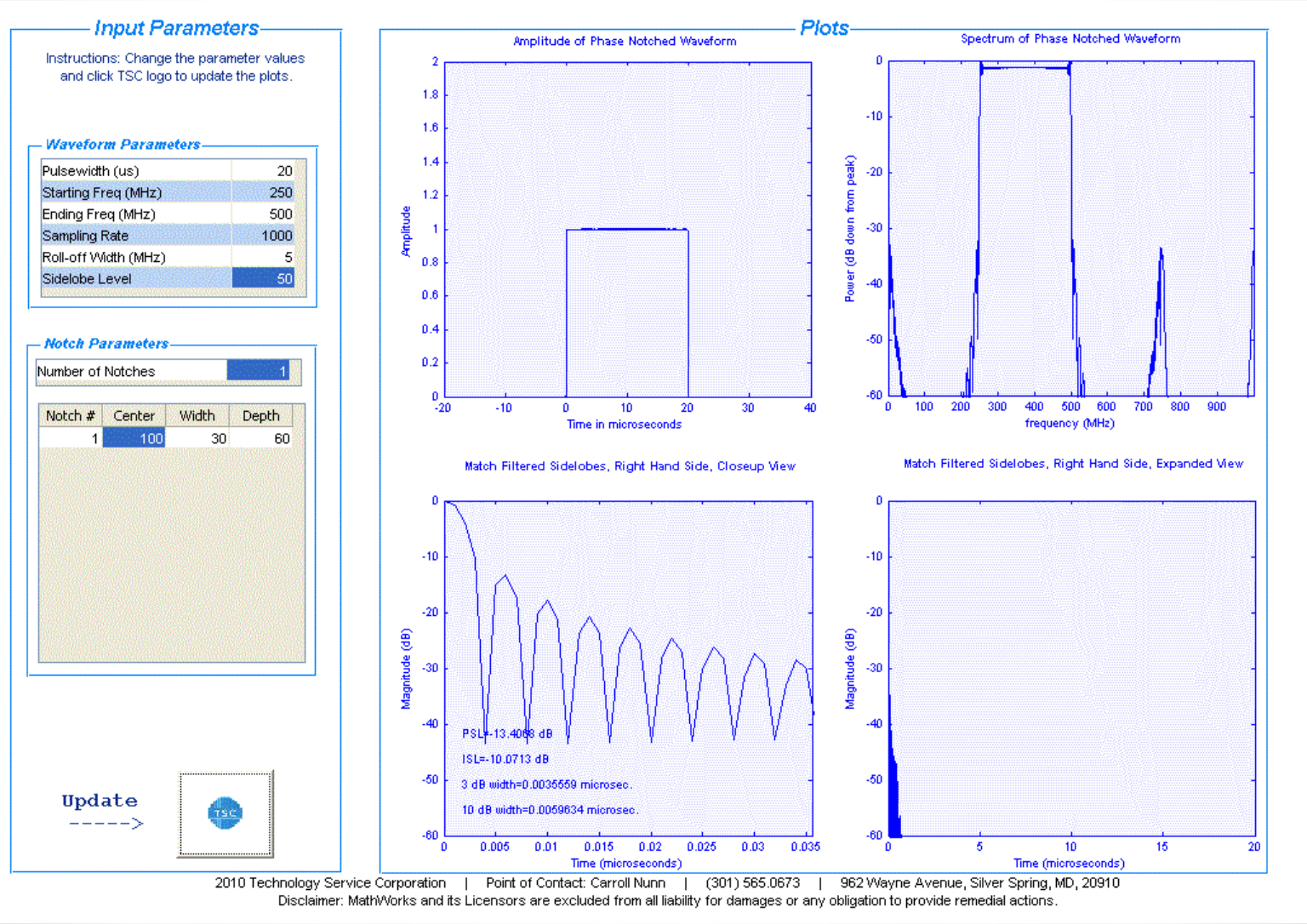
- TSC has developed a unique optimization algorithm which quickly generate waveforms with user defined spectral properties, waveform amplitudes and many other useful properties.
- A Custom Waveform to produce the notches in the earlier example took a few minutes on a desktop PC
- The waveform is constant amplitude, which maintain maximal efficiency. The algorithm is able to carefully control waveform amplitudes to satisfy rise and fall times as well.
- TSC has also developed pre-distortion techniques to insure that the waveform properties are fully realized at the output of the transmitter

Example Custom Waveform

- Plot of Custom Waveform with notches 2.5 – 2.6 GHz and 2.70 – 2.75 GHz



Easy interface to create custom waveforms



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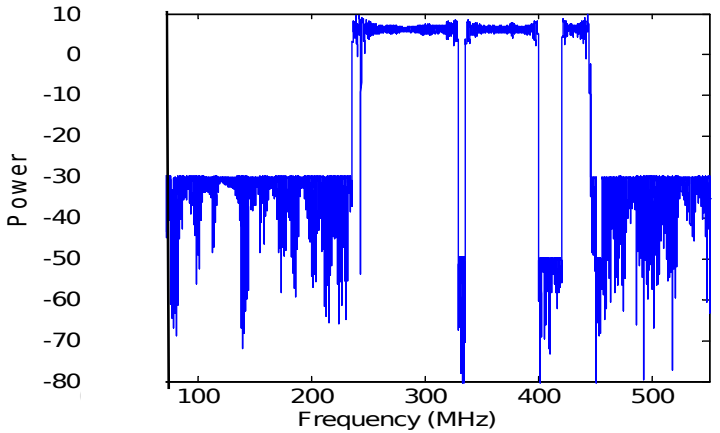
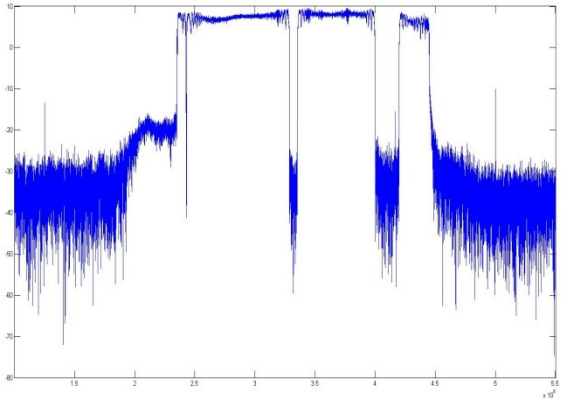
Examples of Transmitted Custom Waveforms

- An example of a custom waveform in an active DoD system
- Designed waveform for a 60 dB depth in notch
- Actual performance resulted in 35 dB depth
  - Transmitter hardware limits notch depths
- Pre-distortion technique was not applied in this example
  - With pre-distortion technique, performance is expected to improve further



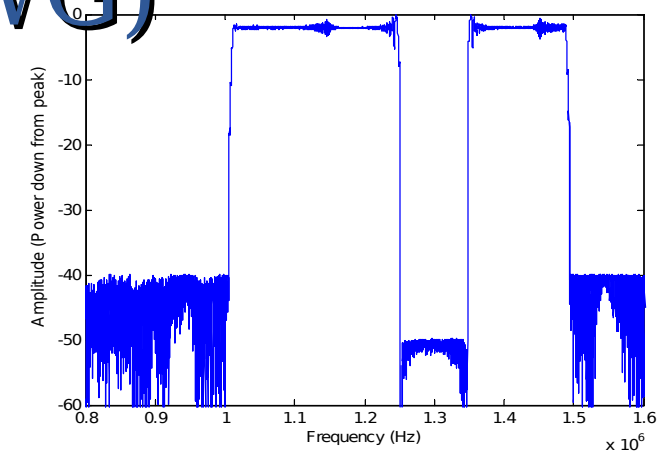
Three notch waveform applied to an airborne radar



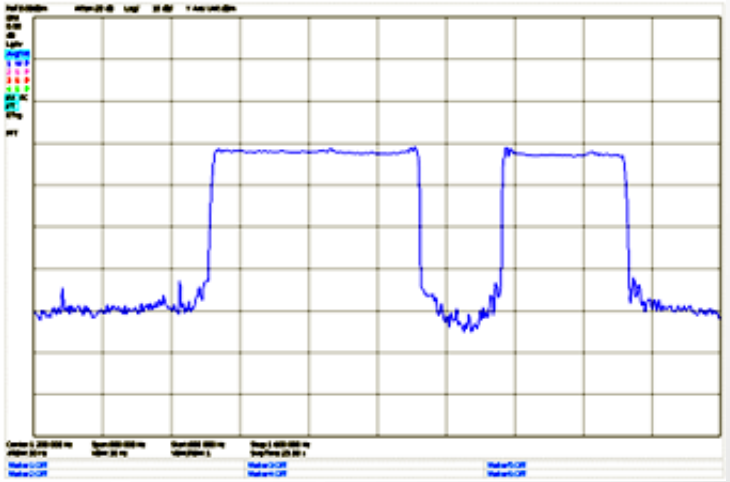
Operational output without using pre-distortion

Output using Agilent 33250A Arbitrary Waveform Generator (AWG)

- Designed waveform for a 50 dB depth in notch
- Actual performance resulted in little better than 40 dB depth
- The Agilent 33250A Arbitrary Waveform Generator (AWG) is low cost COTS, better results are achieved with higher quality generators



Single notch waveform plotted in MatLab



Output of Agilent AWG

Custom Waveforms are in Operational use today

- Currently used on UAV Radar Systems where spectral Requirements change depending on geographic location
- A radar currently under development is using a TSC Waveform to avoid interfering with another DoD radar system in the same frequency band
  - The radar is using part of the spectrum it couldn't otherwise use due to interference of a second radar
- Application can be used to support Communications in the areas of:
  - Spectral Compliance
  - LPI/LPD (Low Probability of Intercept/Detection),
  - High Power Added Efficiency
  - Increase in Data Rates

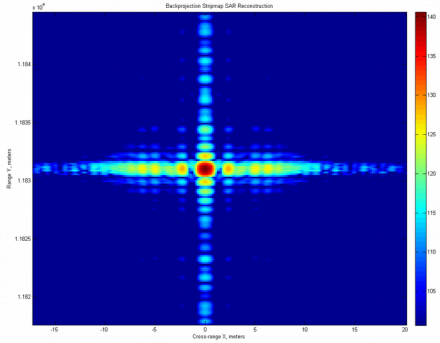
Recovering From Performance Degradation Caused by Spectral Notching

- When parts of the spectrum are notched out, waveform performance can suffer
- In particular the ability to detect small objects in the presence of larger objects or in the presence of many closely spaced objects degrades as the notch sizes increase
- This degradation can be partially reversed through use of mismatched filters and through application of TSC's Forensic search process which is described in subsequent slides

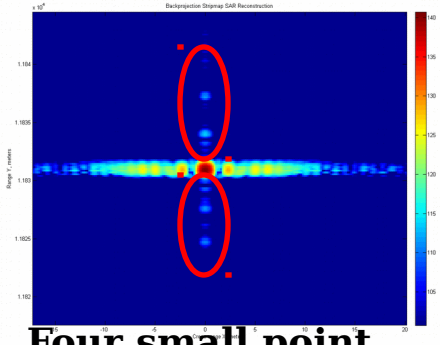
“Forensic” Search

- TSC has developed a mismatched filtering process which can be used to unmask very small objects which would normally be masked by much larger targets
  - An example of such a small target being masked by a larger target would be a missile launcher or military vehicle next to a large building

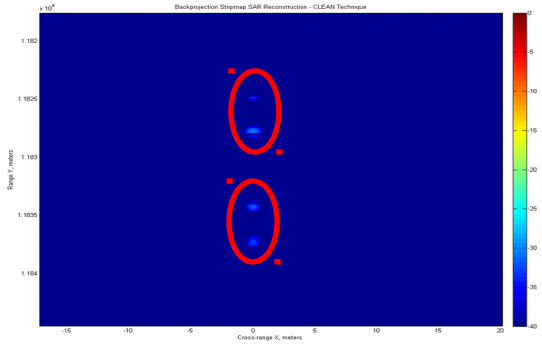
- The slides below show simulated example of a SAR image in which TSC uses Forensic search to unmask four small targets near a large target



Single large discrete in the center of the scene



Four small point targets become visible after Forensic Image



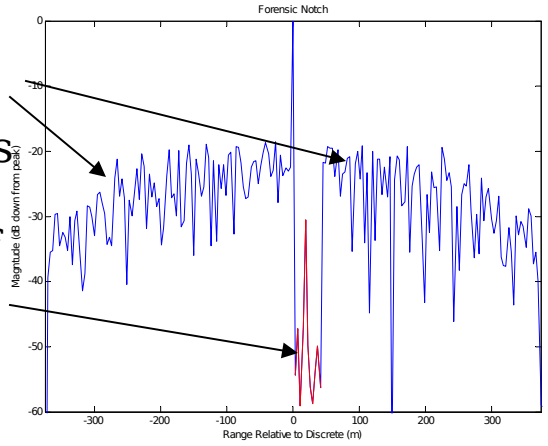
Four small point targets after removing large target

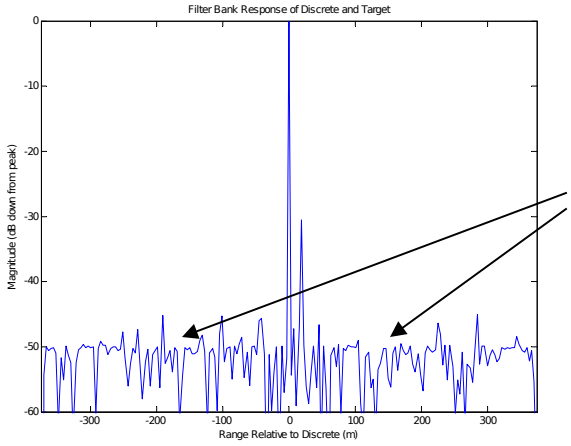
Using Mismatched Filters for Forensic Search

- Well designed radar waveforms allow for the ability to resolve closely spaced objects after processing
  - Depending on the waveform there is always a limit beyond which large targets can mask or hide smaller nearby targets
- TSC's forensic search process allows these small objects to be unmasked and identified near the very large objects

Large Time Sidelobes

Object of Interest in notch

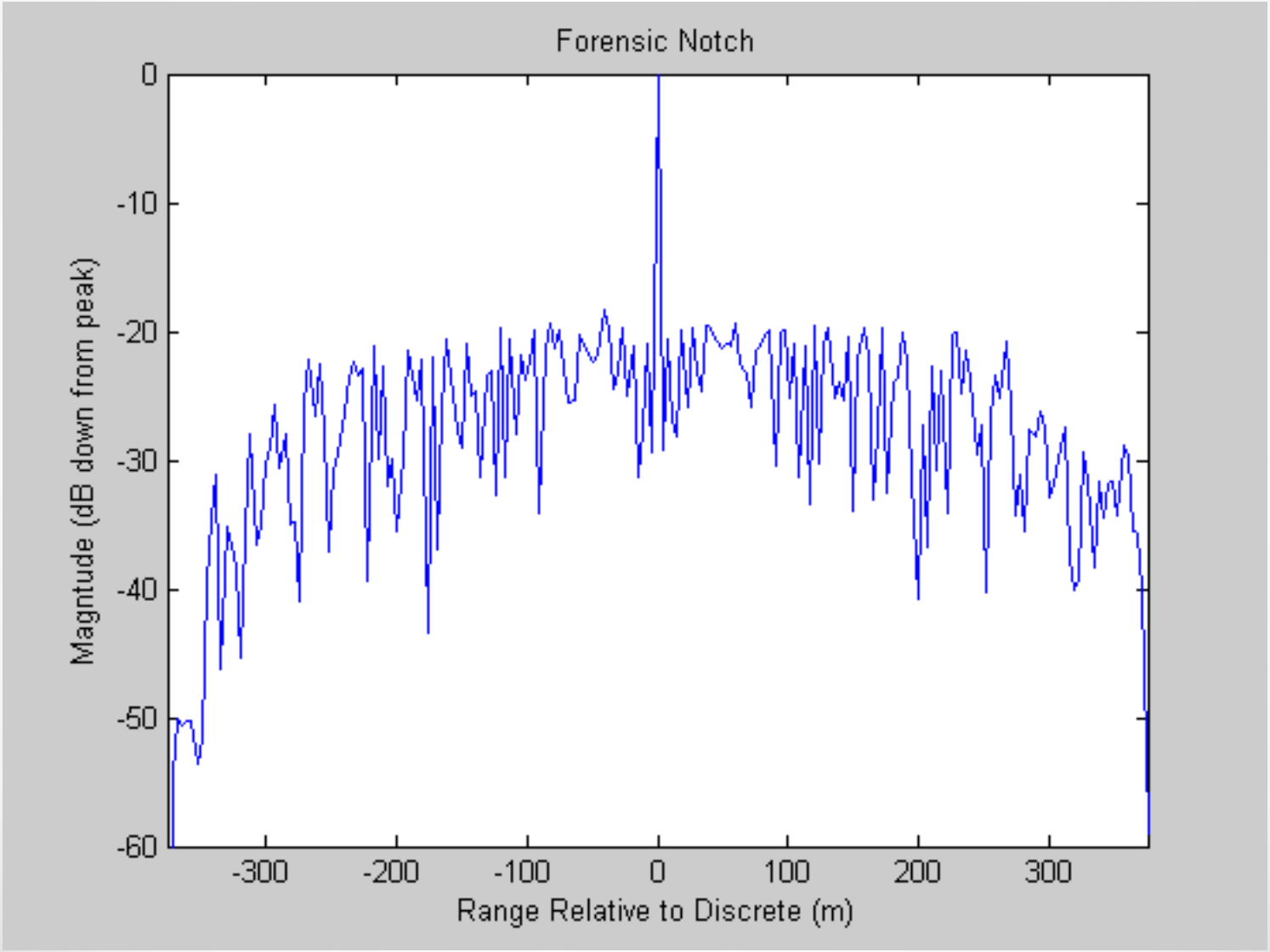




Time Sidelobes everywhere after processing

Forensic Search Example

(requires slideshow mode to properly view)



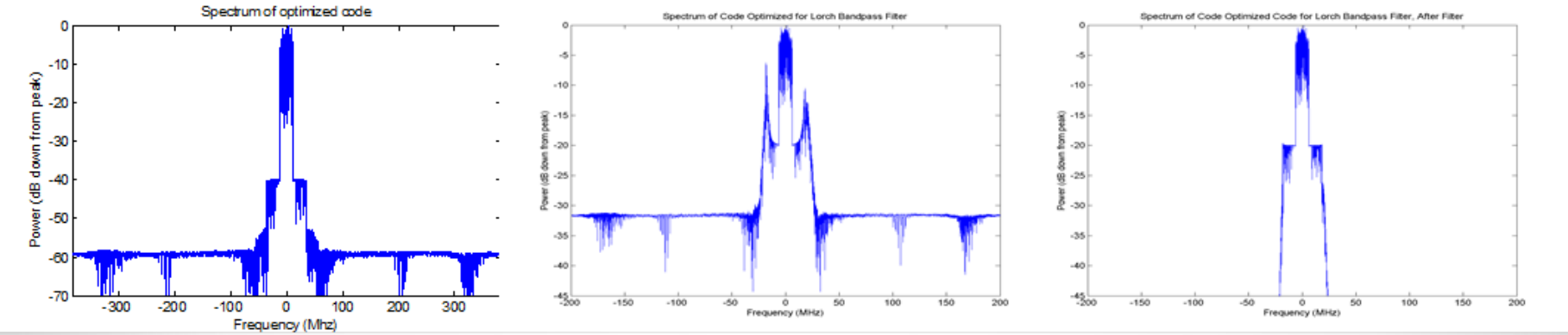
Digital Pre-distortion

- All electronic devices cause some level of change or distortion to signals
- This distortion is unique to the individual device and it evolves as the device ages
- An approach which can be used to account for this distortion is based on careful measurement of how the device changes the signals (i.e. measure the devices Transfer Function) and use that information to modify or pre-distort the signal so that the output signal is as desired

TSC has developed the capability to pre-distort the a waveform to compensate for the transmitter inherent distortion

A Pre-distortion Example

- Below left is the spectrum of a waveform with carefully designed in-band spectral components
- The middle plot represents the spectrum of a waveform which might be input into the transmit chain of a High Powered Amplifier in order to output the signal on right which maintains these desirable in-band spectral components at the output of the transmit chain


Spectrum of optimized code
Power (dB down from peak)
Frequency (Mhz)
Spectrum of Code Optimized for Lorch Bandpass Filter
Power (dB down from peak)
Frequency (MHz)
Spectrum of Code Optimized Code for Lorch Bandpass Filter, After Filter
Power (dB down from peak)
Frequency (MHz)

a) Desired Signal Spectrum

b) Pre-distorted HPA input spectrum

c) Simulated HPA Output Spectrum

Conclusion

- TSC has developed a suite of tools which can be used to create radar and communications waveforms with carefully controlled spectral and time domain components
- The use of these tools can do much to help sensors continue to operate at or near maximum performance efficiency under growing spectral crowding environments

Backup

TSC Hardware Demo

- Please feel free to visit the TSC table for further discussion and demonstration